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(54) Immunological measuring method.

(57) Antigen or antibody is fixed on a solid surface and antibody or antigen attached to fluorescent particle is added thereto and fluorescent particles coupled to antigen or antibody on the solid surface are picked up by a TV camera through a fluorescent microscope and a resultant image is processed similarly. Alternatively, after a suitable time period, antigen or antibody which is not coupled to antibody or antigen on the solid surface is separated from the latter and the coupled fluorescent particles are dis-

solved and measured by a fluorometer.

IMMUNOLOGICAL MEASURING METHOD

The present invention relates to an immunological measuring method in clinical test and, particularly, a high sensitivity immunological measuring method for antigen-antibody reaction utilizing fluorescent particles and an apparatus therefor.

A latex agglutination immunological measuring method utilizing latex constituting fluorescent particles which can be used in the present invention can be classified, generally, to the so-called slide glass method which is a qualitative immunological measuring method, a quantitative immunological measuring method in which an agglutination caused by an antigen-antibody reaction is picked up as a variation of turbidity which is optically measured by a nephelometer (cf. "Latex Photometric Immunoassay (LPIA)", Kensa To Gijutsu, Vol. 12, No. 7, pp. 581, 1984, Japanese Patent Application Laid-open Nos. 24015/1978 and 187264/1984, etc.) and a method utilizing a phenomenon that two or more latex particles are agglutinated for antigen-antibody reaction in which the degree of agglutination of latex is numerically detected by a particle counter of electroresistive type or optical type (cf. " Particle Counting Immunoassay (PACIA)", J. of Immuno. Meth., Vol. 18, page 33, 1977, FCM, Japanese Patent Application Laid-open No. 81567/1987).

The method which uses the nephelometer is advantageous over the enzyme immunoassay (EIA) in that the time necessary for reaction is short and there are highly automated apparatuses for performing it. However, since the sensitivity thereof related to immunological reaction is low compared with the EIA or RIA (Radio Immunoassay), it can not be used for detection of a minute sample which requires high sensitivity. Further, a measuring result obtained by the method using the nephelometer is disadvantageously affected by substances such as chylus serum and immunocomplex coexisting with a test sample. Although in order to eliminate this problem, there have been proposed methods such as a method using near infrared ray and the so-called rate method in which a variation rate of turbidity with time is measured, it is still insufficient to obtain an acceptable sensitivity for immunoassay.

The method using the particle counter is theoretically highly sensitive. However, also in this method, substances coexisting with the latex may cause noise. Further, since, in performing this method, it is necessary to flow a fluid through a very thin nozzle, there is a clogging problem of the nozzle by dust etc. In addition, since, in this method agglutination is measured while it is moving through the nozzle, there is a problem of decomposition of agglutinated substances.

An object of the present invention is to provide a novel high sensitive immunological measuring method and an apparatus for performing the same.

Fluorescent particle carrying antigen or antibody to be used in the present invention can be prepared according to technique disclosed in e.g. Japanese Patent Application Laid-open No. 81566/1987, 81567/1987 or 116264/1987. As latex of this fluorescent particle, other materials than polystyrene disclosed in the above disclosures, such as styrene butadiene copolymer or styrene-acrylic acid copolymer, may be used. As the fluorescent material, organic fluorescent material such as fluorescein or rhodamine, inorganic fluorescent material such as platinum cyanide or sulfates of alkaline earthmetals or any combination thereof may be used. Any antigen or antibody may be attached to the particle. For example, antibody such as cancer marker or HB_s or antigen such as I_g G or I_g M may be used. These substances may be attached to the particle by physical adhesion or chemical reaction utilizing functional groups on the particle.

Further, it is possible to use minute crystals of fluorescent dye of naphthalimide or benzotriazole type directly as carriers for attaching antibody or antigen to latex particles.

The size of the fluorescent particle is not limited so long as the amount of fluorescent light emitted thereby is enough to be measured as a point light source. This is advantageous over the conventional agglutination measuring method using the particle counter which requires the use of latex having a size of around 1 μm in that particle size usable is in the order of 0.1 μm or even smaller which is detected by the conventional particle counter as noise, since the agglutination reaction has a higher speed with smaller particle size. However, when a centrifugal separation of fluorescent particles is employed, the size of the particle should be selected suitably, since it is impossible to apply the centrifugal separation to too small particles.

An apparatus for performing the present method comprises a fluorescent microscope, a TV camera associated therewith and an image processor.

In the drawing:

Fig. 1 shows an embodiment of an apparatus for performing the present method, in block;

Figs. 2 and 3 are graphs showing relations of concentration of AFP to total area of agglutination, respectively; and

Fig. 4 is a graph showing a relation of total number of adsobed latex particles to absolute value of AFP.

In Fig. 1 which is a block diagram of an apparatus for performing the present method, a fluorescent microscope 2 is disposed such that a TV camera 3 can pick up a fluorescent particle image in a cuvette 1 therethrough. A video image obtained by the TV camera 3 is processed by an image processor 4. It is preferable to use, additionally, a microcomputer 5 for digitizing the image, a ultra violet ray source such as high voltage mercury tube 6 emitting an exciting light, a monitor television (not shown) for displaying an output of the microcomputer and a printer (not shown) for printing the output.

The cuvette 1 is of a block or other colored material and has a depth as thin as about 1 mm. An image obtainable by the use of the cuvette 1 and the fluorescent microscope 2 may be changed time to time due to convection in the cuvette. However, with the use of the cuvette 1 having such depth, it is possible to pick up fluorescent particles therein with the fluorscent microscope 2 focussed thereto. Thus, an autofocus mechanism for automatically focussing the fluorescent microscope which is not commercially available can be omitted.

The wavelength and intensity of light from the light source 6 may be selected according to a fluorescent material to be contained in the particle.

The image processor 4 comprises a video input portion, a digital image memory portion for storing data of respective images and a data output portion for supplying the data to the computer on demand.

The image processing is based on a difference in fluorescent light intensity between fluorescent particles agglutinated and those not agglutinated. That is, particles which emit light not lower than a predetermined level are measured. The measurement is any of the counting of the particles, the measuring of an area formed by the particles and the calculation of mean particle size from the area and the number of the particles and a result is digitized by the microcomputer. A standard solution of antigen or antibody is used in an actual measurement and numerical values obtained at respective concentration of the solution are plotted to obtain detection lines.

EXAMPLE 1 MEASUREMENT OF HUMAN AFP

(1) PREPARATION OF REAGENT

Fluorescent polystyrene latex (Fluoresbrite, registered trademark of Polyscience Co., 17151) having a mean particle size of 0.2 μm) and anti-human AFP antibody (rabit)(DAKO) were used and fluorescent latex attached with anti-human AFP antibody was prepared according to the method of Bernard et al (Clin. Chem., 27(6), 832 (1981)).

(2) FORMATION OF DETECTION LINE

A suspension of the resultant fluorescent latex of 10μℓ was added to 20μℓ of each of standard solutions containing human AFP control solution of different concentrations (Nippon Biotest Kenkyusho) and was agitated at 40° C for 30 minutes. Then, 2mℓ of saline solution containing 5 % Tween 20 was added thereto and agitated. 70μℓ of the resultant solution was taken in the cuvette 1 and the latter was set under the fluorescent microscope 2. An image obtained by the TV camera 3 through the fluorescent microscope 2 was processed by the microcomputer 4 and a result was plotted. Fig. 2 shows detection lines obtained in this manner. In Fig. 2, an ordinate is a sum of areas of agglutinations (PnP) each including two or more latex particles are agglutinated.

EXAMPLE 2 MEASUREMENT OF HUMAN AFP

The same operations as those in the Example 1 were performed, except that fluorescent polystyrene latex was Fluoresbrite 17153 having a mean particle size of 0.75 μm, and detection lines shown in Fig. 3 were obtained.

From Figs. 2 and 3, it is clear that, according to the present method, it is possible to measure antigen or antibody of as small amount as 250 pg/mℓ which is highly sensitive compared with the conventional nephelometric measuring method which can measure in the order of 10 ng/mℓ at most.

In the above described embodiment, the antigen-antibody reaction occurs in the solution in the very shallow cuvette. In order to further improve this method, it is necessary to make the depth of the cuvette as small as possible. According to a second aspect of the present invention, antigen or antibody is fixed on a surface to form a solid phase and a suspension containing antibody or antigen attached to fluorescent latex particles is poured onto the solid phase antigen or antibody, so that a reaction occurs in substantially a plane. A microplate of polystyrene having a flat bottom, which is used for ELISA or EIA, or a microplate used for HLA typing may be suitable for the solid phase used in this invention.

An image of the cuvette obtained through the fluorescent microscope includes fluorescent latex coupled to the bottom of the microplate and latex

floating in the solution near the solid phase while not coupled thereto. When the cuvette is of transparent material, it is possible to obtain the former latex efficiently by adding back pigment to the solution after the reaction completes.

The latter latex can be removed by obtaining a plurality of images sequentially and picking a latex image containing latex particles existing all of the images. This is because that non-coupled latex particles move freely while coupled particles are not. Thus, it is possible to pick up only the latex image composed of the coupled latex particles by averaging luminance of each pixel of the data of the plurality of the images and, by plotting a relation between the number of the coupled latex particles and the titer of the immunological component, a detection line can be obtained.

EXAMPLE-3

(1) PREPARATION OF LATEX REAGENT HAVING ANTI-HUMAN α-FETOPROTEIN MONOCLONAL ANTIBODY

1 mℓ of Tris buffer solution (tris-(hydroxymethyl) aminomethane buffer solution) of anti-human α- fetoprotein (AFP) monoclonal antibody (antibody concentration:100 μg/mℓ) was mixed with 100μℓ of fluorescent polystyrene latex (Polyscience Co., concentration of solid phase component: 2.5 wt%) having a mean particle size of 0.3 μm and the mixture was agitated at 37° C for one hour and then centrifugally separated (12,000 rpm, 30 minutes).

Latex attached with anti-AFP monoclonal antibody and separated as above was washed three times with tris buffer solution containing 1.0 wt% bovine serum albumin such that a solution containing 0.002 wt% latex particles suspended is obtained.

(2) PREPARATION OF PLATE REAGENT ATTACHED WITH ANTI-HUMAN α- FETOPROTEIN MONOCLONAL ANTIBODY

Phosphate buffer solution containing anti-human AFP monoclonal antibody having antigen recognition position different from that of anti-human AFP monoclonal antibody prepared in (1), (antibody concentration: 10 ug/mℓ) was poured to a flat bottomed plate (Nunc Co.) having a plurality of wells by an amount of 50 uℓ /well and, after kept stationarily for 4 hours at room temperature, washed three times with phosphate buffered saline (Tw-PBS) containing 0.01 wt% Tween 20.

Thereafter, phosphate buffer solution containing 1.0 wt% bovine serum albumin was added thereto by an amount of 100μℓ /well and, after kept stationarily at 4° C for one night, the mixture was washed three times with Tw-PBS, resulting in the aimed plate.

(3) FORMATION OF STANDARD LINE

Tris buffer solution containing 1.0 wt% bovine serum albumin was added to the plate obtained in (2) by an amount of 10 μℓ /well and antigen-antibody reaction was allowed to occur at room temperature for one hour. Then, the latex prepared in (1) was added by an amount of 50μℓ /well and antigen-antibody reaction was allowed to occur at room temperature for 3 hours.

Thereafter, black ink was added by an amount of 200μℓ /well, and the plate was set to an inverted fluorescent microscope and an image was photographed with a high sensitive film (ISO 3200). Then, the number of latex particles adsorbed on the plate was counted and a standard curve was obtained. Fig. 4 shows the obtained standard curve together with other standard curves obtained by changing time for which the last antigen-antibody reaction occurs.

EXAMPLE-4

The steps (1) and (2) in the Example-3 were used to prepare the latex reagent and the plate reagent. After antigen-antibody reaction for three hours in the step (3) in the Example-3, the plate was washed three times with phosphate buffered saline containing 0.01 wt% Tween 20 to remove particles which were not coupled to the plate.

Then, 200μℓof 95% ethanol was added to each well of the plate and fluorescent particles coupled to the plate were dissolved. Thereafter, dose of fluorescence of the respective wells were measured by using a fluorescent microplate reader with which a standard curve was obtained. This example may be advantageous in that it does not require any image processing technique necessary in the preceding examples.

Evaluation of antigen-antibody reaction to be performed by the standard curves will be clear for those skilled in the art.

As described hereinbefore, according to the present invention, it becomes possible to measure as small amount of antigen or antibody as 250 pg/μ m which can not be measured by the conventional nephelometric measuring method. Further, since, in the present invention, the particle size of

latex is very small, the reaction speed is very high necessarily, and there is no noise problem due to coexisting substances. Further, since, in the present invention, only the coupled fluorescent particles are picked up, it is possible to amplify a signal therefrom with a high amplification factor, resulting in a highly sensitive immunological measurement.

Although, according to the present method, a sample of low concentration can be measured, resulting in high sensitivity, it may be possible to shorten the measuring time considereably if a sample of as high concentration as in the conventional case can be used.

Claims

1. An immunological measuring method comprising the steps of
- preparing fluorescent particles carrying antigen or antibody,
- preparing a reagent containing antibody or antigen, mixing said fluorescent particles with said reagent and allowing antigen-antibody reaction therebetween, and
- measuring those fluorescent particles which are coupled to said reagent.

2. The method of claim 1, wherein the mean size of said fluorescent particles is not more than 0.3 μm.

3. The method of claim 1 or 2, wherein said reagent is put into a shallow cuvette.

4. The method of any one of claims 1 to 3, wherein said mesuring step comprises counting said coupled fluorescent particles.

5. The method of any one of claims 1 to 4, wherein said reagent is in solid phase.

6. The method of claim 5, wherein said measuring step comprises the steps of removing those fluorescent particles not coupled to said reagent and counting the remaining fluorescent particles.

7. The method of claim 5, wherein said measuring step comprises the steps of removing those fluorescent particles not coupled to said reagent, dissolving the remaining particles and measuring the dose thereof.

8. The method of claim 5, wherein said measuring step comprises the steps of obtaining particle patterns successively in time, comparing said patterns to pick-up stable fluorescent particles therein and counting said stable fluorescent particles.

FIG. 1

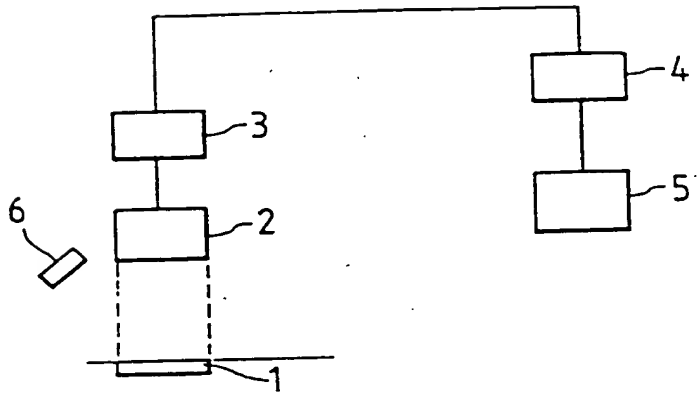

FIG. 2

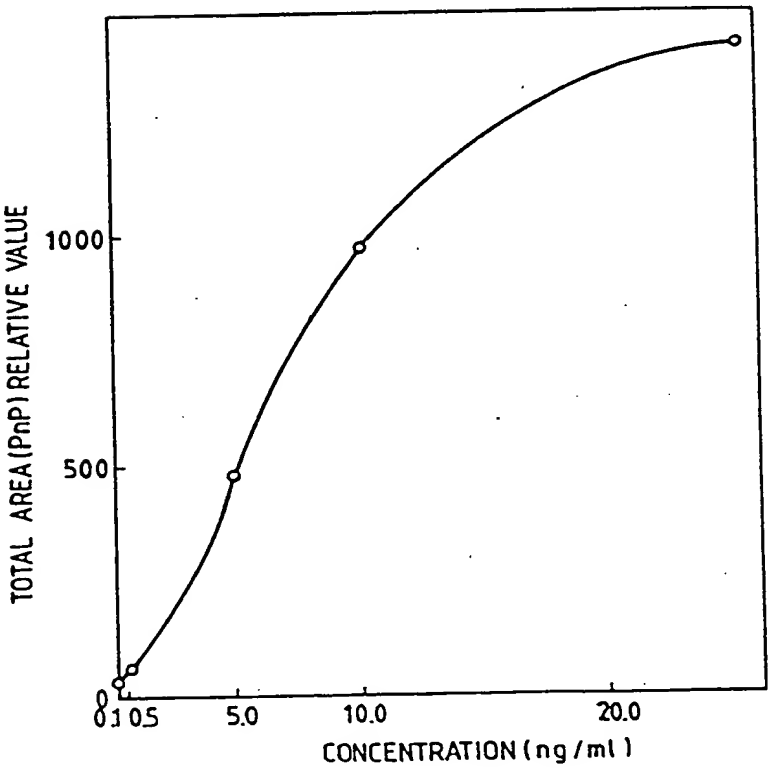

FIG. 3

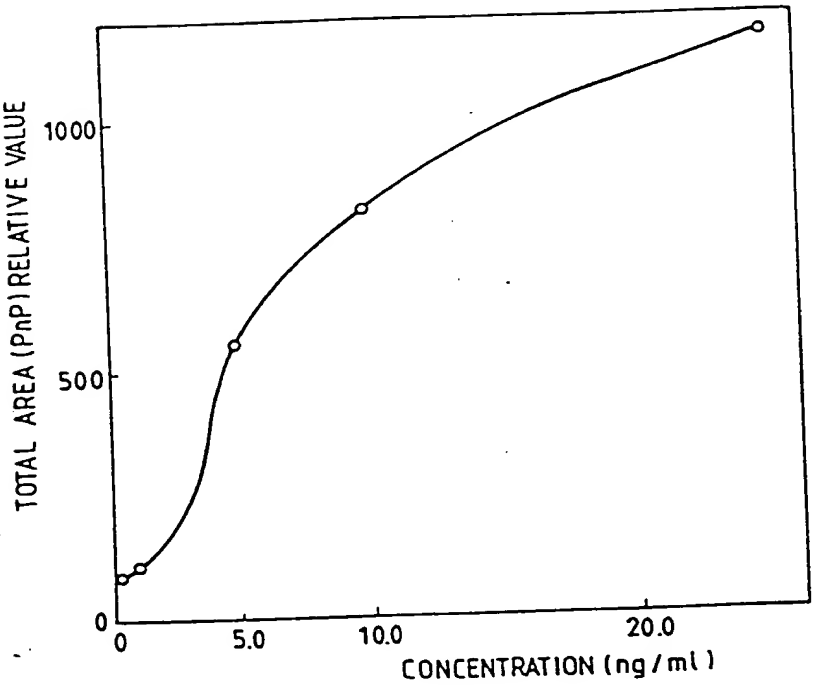

FIG. 4